Combining ability and heterosis for yield and its component traits in rice

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ABSTRACT

Melioration of the genetic architecture of parental lines is the prerequisite for developing high yielding rice varieties. Present investigation was focused on this purpose, comprising ten lines and three testers using line × tester mating design in a Randomized Block Design with three replications. 30 hybrids were phenotyped for yield and its component traits along with their parents. The performance of the material was estimated based on the extent of heterosis, per se *performance and combining ability. Analysis of variance with respect to total treatments revealed significant differences for all the traits studied. among the lines, HPR 2748 (P) was adjudged as the good general combiner for grain yield/plant and other traits whereas, Kasturi was adjudged to be good general combiner for grain yield/plant, plant height, panicle length, spikelets/panicle, grains/panicle, days to 50% flowering, days to maturity and grain length among three testers. The cross HPR 2755 × Kasturi was identified as the best specific combination for grain yield/plantinvolving good × good parental gca effects. Again cross combination HPR 2755 × Kasturi revealed highest heterosis over standard check for grain yield/ plant. Thus, hybrid HPR 2755 × Kasturi was identified as the best combination since it exhibited desirable* per se*, significant* sca *effects and high standard heterosis for grain yield/plant*

Key words: *General combining ability, specific combining ability, heterosis, line x tester analysis*

Rice is an important staple food of almost half of the world population. Rice is grown worldwide over an area of 154 million hectares with total production of 672 million tonnes. Among rice growing countries, India has largest area under rice and ranks second in production. Rice is the staple food for more than 65 per cent of the people of India. Development of a new variety with high yield and quality parameters is the prime objective of all rice breeders. The first step in a successful breeding program is to select appropriate parents. Line x tester analysis provides a systematic approach for selection of appropriate parents and crosses superior in terms of traits. Exploitation of heterosis is primarily dependent on screening and selection of available germplasm that could produce better cross combinations. Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability (*sca*). In breeding high yielding varieties of crop plant, the breeders often face the problem of selecting parents and crosses. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis (Sarker *et al*. 2002; Muhammad *et al*. 2007). The ultimate objective of any crop improvement programme is to improve yield, which is a complex character and is dependent on a number of agro-morphological traits. The degree of heterosis depends on the degree to which parental lines are related. With this background information, the present investigation was taken up to assess combining ability and heterosis in rice.

MATERIALS AND METHODS

Three testers and ten lines were grown during wet season 2013 and at flowering stage; lines and testers were crossed with each other using line x tester mating design to produce 30 F_1 hybrids. The ten lines *viz.*, HPR 2615, HPR 2668, HPR 2720, HPR 2748 (Purple), HPR 2748 (White), HPR 2754, HPR 2755, HPR 2761, HPR

2858 and HPR 2862 and three testers were Kasturi, HPR 2216 (Improved) and Pusa Basmati 1509 (Table 1). F_1s seed were germinated in petri plates by incubation at 30ºC for 48 hours in wet season 2014. Later on these were transferred to trays for raising the seedlings. All the F_1s (30) materials along with their parental lines [lines (10) + testers (3)] at the age of 29 days were transplanted and evaluated in randomized block design with three replications at RWRC, Malan. These genotypes were transplanted in puddled soil. In each replication, entries (F_1s and parents) were grown in single row of 2m length with spacing of 20cm x 15cm. Single seedling was transplanted per hill and all recommended packages of practices were followed throughout the crop growth period.

The data were recorded from five randomly selected competitive plants of each genotype/cross combination for various yield and yield attributing traits studied *viz.*, plant height, total tillers/plant, effective tillers/plant, panicle length, spikelets/panicle, grains/panicle, spikelet fertility, 1000-grain weight and grain yield/plant. Data were also obtained for grain quality traits *viz.*, grain length [L], grain breadth [B], L:B ratio. Days to maturity and days to 50% flowering were recorded on plot basis. The analysis of variance was computed by following the procedure given by Panse and Sukhatme (1964). The combining ability analysis was done by using Line x Tester mating design as described by Kempthorne (1957). The performance of F_1 hybrids was evaluated on the basis of heterosis estimates (Fonseca and Patterson, 1968) and standard heterosis against the best high yielding variety Kasturi.

Table 1. List of rice genotypes used in making crosses in line × tester mating design

Genotypes	Parentage
Lines	
HPR 2615	IR57893/HPR2083
HPR 2668	Palampur Purple/Kasturi
HPR 2720	Pure line selection from IC455333
HPR 2748 (P)	Hassan Serai/T23//IR66295
HPR 2748 (W)	Hassan Serai/T23//IR66295
HPR 2754	Hassan Serai/T23//IR66295-36-2
HPR 2755	Hassan Serai/T23//IR66295
HPR 2761	Hassan Serai/Kasturi
HPR 2858	Palampur Purple/Kasturi
HPR 2862	Palampur Purple/Kasturi
Testers	
Kasturi	Basmati 370/CRR 88-17-1-5
HPR 2216	IR8/IR2053-521-1-1 (HPR 2216/ Tetep derivative)
Pusa Basmati 1509	Pusa 1301/Pusa 1121

RESULTS AND DISCUSSION

Analysis of variance with respect to total treatments revealed significant differences for all the traits studied. Variance due to crosses was also significant for all traits studied. Partitioning of variance of the crosses into lines, testers and lines vs. testers indicated significant differences among lines for plant height, total tillers/plant, effective tillers/plant, panicle length, spikelets/panicle, grain length [L], L:B ratio and 1000-grain weight. Testers also differed significantly for all traits studied, except total tillers/plant, effective tillers/plant and days to maturity. The interaction between lines and testers were significant for all the traits studied except grain breadth indicating the importance of non-additive variance in their expression (Table 2). gca and sca results revealed the predominance of sca variance in relation to gca variance for all the traits studied. Similar results were also observed by Siddiq *et al*. (1992), Satyanarayana *et al.* (2000) and Bisne and Motiramani (2005). The ratio of gca and sca variance was less than unity for all the characters also indicating preponderance of non-additive gene action and suggested good prospects of the exploitation of variation for yield and yield attributes through hybrid breeding (Table 1). Similar results were reported by Kumar *et al.*, 2007; Pradhan and Singh, 2008, Salgotra *et al.*, 2009. The importance of non-additive genes for expression of yield and its components have also been previously reported (Swamy*et al.,* 2003; Malani *et al.*, 2006; Dalvi and Patel, 2009; Saidaiah *et al.,* 2010 and Selvaraj *et al.,* 2011). Further, for grain quality parameters higher estimates of *sca*variances than *gca* variances has also been revealed by Vanaja *et al.* (2003) and Thakare *et al.* (2010).Investigation of *gca* effects inferred that HPR 2748 (P) was adjudged as the good general combiner for grain yield/plant and other traits among 10 lines. On the other hand Kasturi was adjudged to be good general combiner for grain yield/plant, plant height, panicle length, spikelets/panicle, grains/panicle, days to 50% flowering, days to maturity and grain length among testers. Hence, these good general combiners of males and females can be extensively used in future for hybrid rice breeding programme.

Specific combining ability is also one of the important

Table 2. Analysis of variance for combining ability analysis in line x tester design for grain yield, physiological, phenological and grain quality traits

Sources of variation	Mean Sum of Square						gca	sca	gca/sca
	Replications	Crosses	Lines	Testers	Lines X Testers	Error			
D f	2	29	9	2	18	58			
Plant height	1.842	357.296*	611.893*	969.782*	161.942*	2.082	3.6526	53.2868	0.0685
Total tillers/plant	1.152	10.906*	20.502*	6.421	6.605*	0.986	0.0804	1.8733	0.0429
Effective tillers/plant	1.147	10.827*	20.519*	6.295	6.485*	0.985	0.0812	1.8333	0.0443
Panicle length	3.219	30.903*	18.645*	327.964*	4.024*	0.491	0.5026	1.1773	0.4269
Spikelets/panicle	65.494	6298.232*	6195.213*	47936.603*	1723.255*	27.402	85.5411	565.2845	0.1513
Grains/panicle	72.665	7509.508*	4011.628	70283.224*	2283.591*	48.961	97.7122	744.8767	0.1312
Grain fertility	6.321	526.364*	196.549	3075.113*	408.078*	6.623	2.2117	133.8181	0.0165
1000-grain weight	3.804	32.833*	29.300*	263.450*	8.975*	0.803	0.4461	2.7238	0.1638
Grain yield/plant	1.045	172.004*	152.058	1146.701*	73.676*	3.943	1.8385	23.2446	0.0791
Days to 50% flowering	0.300	110.966*	29.506	969.233*	56.332*	1.541	1.0215	18.2636	0.0559
Days to maturity	3.344	3.433*	5.506	3.011	2.443*	0.322	0.0185	0.7073	0.0262
Grain length [L]	1.432	2.365*	2.040*	21.028*	0.453*	0.056	0.0357	0.1324	0.2696
Grain breadth [B]	0.005	0.024*	0.017	0.209*	0.007	0.004	0.0003	0.0010	0.3000
L:B ratio	0.362	0.742*	0.581*	6.907*	0.137*	0.018	0.0113	0.0395	0.2861

* Significant at 5% level of significance

criteria for evaluation of superior hybrids. Specific combining ability showed the importance of a particular cross in the exploitation of heterosis. The hybrids *viz.*,HPR 2755 × Kasturi, HPR 2754 × HPR 2216, HPR 2761 × Pusa Basmati 1509, HPR 2720 × HPR 2216, HPR 2754 × Pusa Basmati 1509, HPR 2748 (P) × HPR 2216, HPR 2755 × HPR 2216, HPR 2668 × Kasturi, HPR 2754 × Kasturi and HPR 2615 × HPR 2216 were adjudged as the specific combiner which showed desirable *sca* effects for various traits (Table 3). None of the cross combinations were found to be good specific cross combinations for all the traits simultaneously. However, the cross combination HPR 2755 × Kasturi was identified as the best specific combination for grain yield/plant followed by HPR 2754 × Pusa Basmati 1509, HPR 2615 × Kasturi, HPR 2720 × HPR 2216, HPR 2754 × HPR 2216, HPR 2748 (P) × Pusa Basmati 1509 and HPR 2748 (W) × Pusa Basmati 1509 involving good × good, average × poor, poor × good, poor × poor, average × poor, good × poor and poor × poor gca effects of the parent, respectively (Table 4). This revealed that expression of sca effects were independent of the gca combinations that is sca effect of any cross combination does not essentially depend upon the *gca* effects of the parent (Sarsar *et al*., 1986; Ramalingam *et al*., 1993).

Further more; it was observed that significant positive heterosis exhibited by as many as twenty two crosses over better parent and twenty four crosses over standard check for grain yield/plant. Heterosis over better parent for grain yield/plant ranged from -16.93 to 157.77 per cent. However, when compared with standard check it ranged from -28.34 to 157.77 per cent. Among total crosses, twenty four cross combinations were superior in grain yield/plant than the standard check variety. Out of these potential cross combinations HPR 2755 × Kasturi followed by HPR 2748 (P) × Kasturi, HPR 2862 × Kasturi, HPR 2615 × Kasturi, HPR 2668 × Kasturi and HPR 2748 (W) × Kasturi were ranked among top six crosses with respect to highest heterosis over standard check for grain yield/plant which is indicating that these crosses have the good capability for the development of hybrid rice (Table 5).

Alone *sca* effects may not be considered for heterosis exploitation as hybrids with low *per se* may also possess higher *sca* effects. Moreover, heterosis value alone may also mislead the identity of fabulous hybrids. So exploitation of hybrids for heterosis breeding is best judged by *per se*, *sca* effects and magnitude of heterosis. Based on this credible way, the hybrid HPR 2755 × Kasturi is suitable for heterosis breeding, since

Table 3. List of heterotic crosses over standard check (%), good specific combinations and good general combiners for yield, physiological, phenological and grain quality traits

Traits / Heterotic crosses	Good specific combinations	Good general combiners
Yield and physiological traits		
Plant height		
HPR 2668 × Pusa Basmati 1509 (-11.67)	HPR 2761 × Pusa Basmati 1509	HPR 2761
HPR 2748 (W) × Pusa Basmati 1509(-11.51)	HPR 2720 × Pusa Basmati 1509	HPR 2720
HPR 2755 × Pusa Basmati 1509 (-10.84)	HPR 2754 × Pusa Basmati 1509	HPR 2862
HPR 2748 (P) × Pusa Basmati 1509 (-7.02)	HPR 2748 (W) × HPR 2216	Kasturi
Total tillers/plant		
HPR 2748 (P) × HPR 2216 (156.52)	HPR 2748 (P) × HPR 2216	HPR 2748 (P)
HPR 2754 × Pusa Basmati 1509 (115.22)	HPR 2754 × Pusa Basmati 1509	HPR 2755
HPR 2755 × Kasturi (97.83)	HPR 2755 × Kasturi	HPR 2748 (W)
HPR 2748 (P) × Pusa Basmati 1509 (91.85)	HPR 2720 × HPR 2216	HPR 2216
Effective tillers/plant		
HPR 2748 (P) × HPR 2216 (156.32)	HPR 2748 (P) × HPR 2216	HPR 2748 (P)
HPR 2754 × Pusa Basmati 1509 (110.87)	HPR 2754 × Pusa Basmati 1509	HPR 2755
HPR 2755 × Kasturi (95.65)	HPR 2755 × Kasturi	HPR 2748 (W)
HPR 2748 (P) × Pusa Basmati (91.85)	HPR 2615 × Kasturi	HPR 2216
Panicle length		
HPR 2862 × Kasturi (6.50)	HPR 2754 × HPR 2216	HPR 2862
HPR 2720 × Kasturi (5.22)	HPR 2761 × Pusa Basmati 1509	HPR 2720
HPR 2720 × Kasturi	HPR 2858	
HPR 2862 × Kasturi	Kasturi	
Spikelets/panicle		
HPR 2862 × Kasturi (102.08)	HPR 2720 × HPR 2216	HPR 2862
HPR 2668 × Kasturi (65.62)	HPR 2615 × Pusa Basmati 1509	HPR 2720
HPR 2755 × Kasturi (61.66)	HPR 2862 × Kasturi	HPR 2858
HPR 2720 × Kasturi (60.26)	HPR 2754 × Pusa Basmati 1509	Kasturi
Grains/panicle		
HPR 2862 × Kasturi (89.56)	HPR 2754 × Pusa Basmati 1509	HPR 2862
HPR 2755 × Kasturi (57.78)	HPR 2615 × Pusa Basmati 1509	HPR 2720
HPR 2668 × Kasturi (51.70)	HPR 2720 × HPR 2216	HPR 2858
HPR 2720 × Kasturi (49.68)	HPR 2858 × HPR 2216	Kasturi
1000-grain weight		
HPR 2858 × Pusa Basmati 1509 (48.05)	HPR 2754 × HPR 2216	HPR 2858
HPR 2748 (P) × Pusa Basmati 1509 (42.46)	HPR 2761 × Pusa Basmati 1509	HPR 2862
HPR 2862 × Pusa Basmati 1509 (41.81)	HPR 2858 × Pusa Basmati 1509	HPR 2748 (P)
HPR 2761 × Pusa Basmati 1509 (38.68)	HPR 2748 (W) × Kasturi	Pusa Basmati 1509
Grain yield/plant		
HPR 2755 × Kasturi (157.77)	HPR 2755 × Kasturi	HPR 2748 (P)
HPR 2748 (P) × Kasturi (124.99)	HPR 2754 × Pusa Basmati 1509	HPR 2755
HPR 2862 × Kasturi (114.03)	HPR 2615 × Kasturi	HPR 2862
HPR 2615 × Kasturi (105.05)	HPR 2720 × HPR 2216	Kasturi
Phenological traits		
Days to 50% flowering		
HPR 2668 × HPR 2216 (-18.27)	HPR 2755 × HPR 2216	HPR 2754
HPR 2755 × Kasturi (-18.27)	HPR 2720 × Kasturi	HPR 2862
HPR 2761 × HPR 2216 (-18.27)	HPR 2862 × Kasturi	HPR 2720
HPR 2858 × HPR 2216 (-18.27)	HPR 2754 × Kasturi	Kasturi

Table 3....contd...

Traits / Heterotic crosses	Good specific combinations	Good general combiners
Days to maturity		
HPR 2748 (P) × Pusa Basmati 1509 (-1.28)	HPR 2668 × Kasturi	HPR 2858
HPR 2754 × HPR 2216 (-1.28)	HPR 2761 × Pusa Basmati 1509	HPR 2862
HPR 2754 × Pusa Basmati 1509 (-1.28)	HPR 2748 (P) × Kasturi	HPR 2720
HPR 2761 × Kasturi (-1.28)	HPR 2754 × Kasturi	Kasturi
Grain quality traits		
Grain length [L]		
HPR 2761 × Pusa Basmati 1509 (18.62)	HPR 2754 × Kasturi	HPR 2761
HPR 2862 × Pusa Basmati 1509 (13.33)	HPR 2761 × Pusa Basmati 1509	HPR 2862
HPR 2748 (W) × Pusa Basmati 1509 (12.49)	HPR 2754 × HPR 2216	HPR 2748 (P)
HPR 2858 × Pusa Basmati 1509 (11.45)	HPR 2720 × HPR 2216	Kasturi
Grain breadth [B]		
HPR 2615 × HPR 2216 (24.91)	HPR 2615 × HPR 2216	HPR 2615
HPR 2858 × HPR 2216 (20.76)		HPR 2858
HPR 2755 × HPR 2216 (19.38)		HPR 2216
HPR 2748 (P) × HPR 2216 (15.74)		
L:B ratio		
HPR 2761 × Pusa Basmati 1509 (8.35)	HPR 2754 × HPR 2216	HPR 2761
	HPR 2754 × Kasturi	HPR 2748 (P)
	HPR 2720 × HPR 2216	HPR 2748 (W)
	HPR 2761 × Pusa Basmati 1509	Pusa Basmati 1509

Table 4. Sca and gca of parents for grain yield/plant involved in producing F_1

Specific crosses	sca	gca of parents		gca effects of parent	
		Lines	Testers	Lines	Testers
HPR 2755 × Kasturi	8.77*	4.44*	7.13*	G	G
HPR 2754 × Pusa Basmati 1509	6.39*	0.42	-3.79*	A	P
HPR 2615 × Kasturi	4.49*	-1.03	7.13*	P	G
HPR 2720 × HPR 2216	3.86*	-2.63*	-3.35*	P	P
HPR 2754 × HPR 2216	3.46*	0.42	-3.35*	A	P
HPR 2748 (P) × Pusa Basmati 1509	3.26*	6.54*	-3.79*	G	P
HPR 2748 (W) × Pusa Basmati 1509	3.15*	-0.09	-3.79*	P	P

* Significant at 5% level of significance, G = good, P = poor, A = average

Table 5. Top six potential cross combinations with heterosis per cent and *per se* performance for grain yield/plant along with sca effect

Heterotic crosses	*Per se* performance	Heterosis over standard check (%)	sca effect
HPR 2755 × Kasturi	47.65	157.77*	8.77*
HPR 2748 (Purple) × Kasturi	41.59	124.99*	0.60
HPR 2862 × Kasturi	39.57	114.03*	1.76
HPR 2615 × Kasturi	37.91	105.05*	4.49*
HPR 2668 × Kasturi	35.49	91.99*	0.68
HPR 2748 (White) × Kasturi	34.70	87.70*	0.33

* Significant at 5% level of significance

it exhibited desirable *per se*, *sca* effects and standard heterosis for grain yield/plant (Table 4). Similar findings were reported by Kshirsagar *et al*. (2005) and Utharasu and Anandakumar (2013).

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